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AUTHOR Haney, Richard E.
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ABSTRACT

Some successful innovations and their underlying rationales that were implemented 50, 60, and 70 years ago could be useful in solving many educational problems. Of major concern are the gap between the actual science and mathematics curricula in most schools and the demands placed on everyday living in the modern world dominated by technology and the gap between the actual science and mathematics program in most schools and the needs, interests and abilities of the particular students in those schools. Current reforms such as Project 2061, Project Synthesis, and the National Science Teachers' Association's project on scope, sequence, and coordination are discussed. Integrating science with other subjects, progressive education, and other historical projects are also examined. Included are examples of innovative programs found in the United States. (KR)

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BACK TO THE FUTURE OF SCIENCE AND MATH EDUCATION

Richard E. Haney, Professor Emeritus
Dept. of Curriculum and Instruction
University of Wisconsin - Milwaukee

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Let us begin with two quotes from documents written long ago. The first is from the report of the Conference on Physics, Chemistry and Astronomy of the Committee of Ten which was published in 1893. The concern was with the number of classes a teacher should teach each day considering the amount of work involved in managing science laboratories. "...to give good instruction in the sciences requires of the teacher more work than to teach math or language and the sooner this fact is recognized by (administrators) the better for all concerned."(14).

The second is from John Dewey who was discussing the problems associated with self contained classrooms in his laboratory school at the University of Chicago during the period from 1896 to 1904.

"It was assumed at first that an all-round teacher would be the best and perhaps it would be advisable to have one teacher teach the children in several branches. This theory however, has been abandoned, and it has been thought well to secure teachers who are specialists by taste and training ... One of the reasons for this modification of the original plan was the difficulty of getting scientific facts presented that were facts and truths." (22:123).

There always have been concerns over what subject matter should be included in schools programs, how it should be organized and how it should be taught. Numerous study groups have made recommendations and many innovations have been tried out. But, because of changes in student populations, our improved understanding of needs, interests and abilities of learners, differing viewpoints of educational goals, and limited funding, there probably always will be some "crisis" in education and calls for reform.

The two quotes above are examples of suggestions made at the turn of the century which, if they had been heeded, could have made our current situation in science education very different than it is. What science teacher hasn't wished for more time to manage laboratory work, and how often have we not wondered at the effectiveness of science instruction in elementary schools carried on by teachers in "self-contained" classrooms? Is there nothing new under the sun? How effective have been the numerous movements of reform in the past and what lessons might they hold for those of us who are attempting to meet today's crisis in education?

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I would like to describe some successful innovations and their underlying rationale that were implemented 50, 60, and 70 years ago and to point out how they could be useful in solving many of today's educational problems.

Major Concerns So many special interest groups have expressed varying concerns over science and mathematics education that it is difficult to summarize them adequately. But we must attempt this if we are to evaluate suggestions for reform. Two major gaps need to be addressed. First, there is the gap between the the actual science and mathematics curricula in most schools and the demands placed on everyday living in the modern world dominated by science and technology. This is the gap that usually comes to mind first and which is the focus of many current reform movements. There are two problems associated with this gap. One is the need to provide appropriate science and mathematics in the general education of all students so that all can participate as fully as possible in our society. Democracy won't work if there is not a general science and technological literacy on the part of all citizens. In addition, there is the problem of providing more concentrated instruction in the K-12 program for those students having the interest and ability to pursue a science-based career.

The second major gap is that which exists between the actual science and mathematics program in most schools and the needs, interests and abilities of the particular students in those schools. This gap usually occurs when the make-up of school programs is heavily influenced by special interest groups and subject matter specialists concerned largely with societal demands and then imposed on schools with teachers being left to "motivate" students. School populations have changed over the years, especially in urban areas, and approaches that were successful in one decade can fail in the next. Many students are coming to school now lacking the background of experiences with natural phenomena that are assumed in most science and math programs. Civilization and urban life in particular, shelter most of us from the roots of our existence in nature. This gap arises when we focus on the preparatory function of schools, getting students ready for college and future citizenship, to the neglect of the heavy role that schooling plays in the current lives of children and adolescents. Many cannot tolerate the delayed reward system which says in effect, "study this now because it will make you a better adult five or ten years from now." This is the gap that is manifested by student drop-outs, adolescent alienation and science/math anxiety. It is the lack of personal relevance that many find in their school work.

These two gaps, between actual school practices and (a) the anticipated future needs of students and (b) their current needs, must both be addressed by any reform movement if it is to succeed.

There are other gaps, of course. There is the gap between what the public wants and what it is willing to pay for, the gap between actual school practices, desired practices, and what teachers are being trained and retrained for. Certainly reforms will not last that do not address the problem of public understanding and support and that of teacher education and teacher in-servicing in support of change.

Current Reforms. It will be helpful to first look briefly at the current reform efforts so that we can then recognize their roots in the reform efforts of fifty and sixty years ago. The National Science Teachers Association's Lead Paper on Science and Technology Education for the 21st Century adopted this year contains a number of recommendations that many of the gaps that have been identified. For example:

> Schools should give science a central role in K-5 instruction.
>
> All students in high school should have science courses that meet every day, every year.
>
> (Schools should) develop curricula that provide opportunities for all students and adults to study real-life, personal and societal science and technology problems.
>
> (Schools should) develop a K-12 science curriculum framework that is integrated or correlated in terms of science, technology, mathematics, humanities and the social sciences.
>
> (Schools should) develop and implement science curricula that will prepare students to pursue a career in science and engineering and respond to the growing demand for women in physical science and engineering.
>
> (Schools should) develop materials and programs for instructional administrators, policy makers and lay people (eg., principals, superintendents, school board members, and parents) that would provide better understanding of the goals of science instruction and the facilities, equipment, supplies, and personnel needed to achieve these goals.
>
> (Schools should) establish science supervisors coordinators, and consultants in school districts to give leadership in curriculum and instruction; and

provide ways of getting equipment and supplies to teachers.

(Schools should) mandate and support ongoing staff development programs for teachers of science to enhance their science knowledge and science teaching skills.

(School districts should) support increased use of collegial teams within and among schools as well as networking among teachers to enhance instructional decision making.

These and other recommendations in the paper are intended to support two major goals of producing "a scientifically literate citizenry" and ensuring "an adequate supply of qualified scientists, engineers, and science teachers for the 21st century."

The NSTA Project on Scope, Sequence, and Coordination of Secondary School Science, introduced in 1989, focuses attention on a need for coordination of science instruction over the grade range 7-12. Model sites presently continue to be established throughout the country at which various approaches to spacing of instruction in biology, chemistry, physics, and earth science over this six-year span as opposed to the traditional "layer cake" of separate subjects each year are being investigated. In some instances the identity of the separate subjects is maintained and students spend time on each subject each week. In other cases the subjects are integrated in each of the six years. The rationale for both approaches is that instruction is more effective when students can study a subject over several years' time rather than spending a whole year on a single subject and doing nothing with the others that year. Spreading the subjects over six years also permits instruction to proceed from concrete subject matter to the abstract in a pattern that roughly parallels the developing intellectual abilities of the students. Investigation of these developmental sequences is another major focus of this program.

Meanwhile, the American Association for the Advancement of Science has been progressing with its Project 2061 for science education reform initiated in 1985, the year in which Halley's Comet appeared. It will appear again in 2061 and the children who will be alive to see it then are about to start school. During the initial phase of the project leading scientists and educators laid down the conceptual base for reform by defining scientific literacy in terms of learning outcomes needed by all citizens in the time span between now and the return of Comet Halley. The results of this study are published in Science for All Americans and the separate reports of the scientific panels (2). In

Phase II several alternative curriculum models for achieving the goals identified in Phase I will be explored. Actually implementing educational reform based on the outcomes of this study will be the goal of Phase III which could last a decade or longer.

Project Synthesis. In the 1980's a series of national surveys of science teaching practices culminated in Project Synthesis (11) which produced a number of findings and recommendations. Four broadly defined goal clusters were established to serve as a background against which science programs could be evaluated. They were:

1. Personal Needs. Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.

2. Societal Issues. Science education should produce informed citizens prepared to deal responsibly with science related societal issues.

3. Academic Preparation. Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

4. Career Education/Awareness. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

These goal clusters formed the basis for the development of a series of operational definitions of effective science education. These took the form of "desired states" of various forms of the educational process in each science area. Then the "actual states" of instruction in the sciences as determined by the national surveys were evaluated against this background. Recommendations for improvements in science education emerged in the final phase of the project.

The following generalizations summarize the actual states of K-12 science education in the early 1980's as determined by this project:

1. At all levels, science education in general is given a relatively low priority when compared with the language arts, mathematics and social studies, and its status is declining. This low priority results in a general lack of support for science in most school systems.

2. Textbooks play a dominant role in science instruction.

3. Of the four goal clusters ... only the goals related to development of basic knowledge for academic preparation receive significant emphasis. Goals related to personal use of science in everyday life, to scientific literacy for societal decision-making, and to career planning and decision making are largely ignored.

4. Teachers make most of the important decisions about course content, text selection and instructional methods, and in so doing they determine the goals pursued by science education.

In closing, the authors addressed the challenge of shifting current goals and practices in school districts throughout the nation to those that reflect a balanced emphasis on all four of the goal clusters identified by the project. Among the recommendations for change were increased emphasis on decision-making and problem-solving skills, on human biology and the effect of human activities on the living world as well as our dependence on the environment and our responsibility for preserving it, and on the relationship of science and technology and their roles in modern affairs. The addition of courses dealing with applications of science and technology was recommended. The problems of modifying practices in teacher education and teacher renewal programs to prepare teachers for the new science education were also discussed.

Integrating Science with other Subjects. During the 1980's also, many state departments of public instruction issued revised guides to curriculum development suggesting ways of bringing about these and similar changes within their school districts. For example, Wisconsin's science guide stresses the interaction of science, technology and society and suggests ways in which programs can be developed that relate science and technology to student needs, attitudes and beliefs, to societal needs, and to economic and political realities (6). In addition, the same state's environmental education guide, written by different authors, suggests ways in which environmental education and values clarification can be infused throughout all curricular areas (8). When both of these sets of recommendations are implemented the structures of the traditional science subjects mellow and students come to see the interrelatedness of all they are studying in any given semester. Suggestions are made in both guides concerning the creation of K-12 sequences that correlate with stages in the intellectual development of students during the school years.

Our present reform movement, then, is aimed at closing the gap between actual school practices and those that are needed to develop a scientific and technological literacy among all students that will enable them to function effectively in the modern world. A second concern is providing sufficient academic preparation in science and mathematics for those who will choose a science-based career. Current practices, in general, still tend to be fact and textbook oriented in spite of the exceptions that can be found in scattered exemplary programs. Wider ranging goals have been called for including greater emphasis on meeting students' personal needs, development of greater science-based career awareness, and the relating of science and mathematics to societal, technological and environmental issues. To meet these goals reformers emphasize the need to overcome the isolation of the separate science subjects, to relate them to other school subjects and to relate science and mathematics to real-life situations. Problem solving is advocated as a major learning strategy. Also called for are better coordination of subject matter over the K-12 span and the correlation of learning activities with known stages in the intellectual development of the learners.

Progressive Education Many of these same concerns were voiced by educational reformers as far back as the turn of the century. Then as now, there was concern over subject matter content that was of little relevance to the lives of students and overly formal teaching methods based on an out-dated psychology. The Progresive Education movement which arose at this time represented an effort to use the schools to improve the lives of individuals (5:viii). To this end there was a general effort to make school programs more life-like, to prepare students for democratic living in an increasingly urban-industrial civilization by having them engage in cooperative, democratic learning activities in school. Curricula were broadened to include concern for such practical matters as health and career orientation. Instruction was based on an enlightened understanding of human development and learning and a recognition of individual pupil differences and needs.

In the elementary school much emphasis was placed on the education of the "whole child." Science played an important role in many proposed programs because it provided the means for teaching the critical thinking skills needed by all citizens in a democracy. The 1932 yearbook of the National Society for the Study of Education (17) presented a rationale for a coordinated program of science throughout the grades based on principles of Progressive Education. The 1946 yearbook of the same group placed great stress on developing in students a functional understanding of science concepts and principles (19). In 1938 the Progressive Education Association published Science in General Education, (20) and shortly thereafter, Mathematics in General Education . These explained

the rational which underlay the develpment of innovative programs in these subjects based on an analysis of student needs. To illustrate the detail with which adolescent needs were identified the following analysis of the former book is presented.

Science in General Education, published in 1938 by the Progressive Education Association, was an expression of a theory of science education that emerged during the Progressive Education movement. Particular attention in this theory was paid to the individual learner and his or her environment and to the nature of democracy at all levels of organization from local governments to the federal. A major tenet of the theory was that educational processes and goals must be relevant to the needs of learners as they interact with their social media. Therefore, before science goals and programs could be described the Commission on Secondary School Curriculum conducted a study of adolescent needs and interests. Then, suggestions for science curriculum development and instruction were organized around these. This approach contrasted sharply with the then-current practice of patterning science courses in high school after the separate disciplines as organized in college programs.

Four basic aspects of living or categories of student needs were identified which served as guideposts for curriculum building. These were:

1. Personal Living: how individuals interact with their environment.

2. Immediate Personal-Social Relationships: the development of mature relationships with family and peers.

3. Social-Civic Relationships: the need for social recognition through responsible participation in socially significant activity.

4. Economic Relationships: activities of the individual in production and distribution of goods and services.

Because democracy was highly valued as the social context which fostered the optimum development of personality the needs of democratic society also ranked high in this educational theory. Thus any teacher or curriculum worker was to ask such questions as these about any proposed learning activty: How does it help the student to meet his or her needs in each of the four categories shown above? and, How does it promote the ideals of democracy?

A major portion of Science in General Education was devoted to the elaboration of personal needs in each of the four categories and discussions of science content and

teaching procedures to be incorporated in programs designed to help students meet these needs. To show the extent of this study the needs are outlined below.

I Needs in the area of personal living
- A. personal health
- B. self assurance
- C. satisfying attitude toward the external world and a workable philosophy of life
- D. a range of personal interests
- E. esthetic satisfaction

II Needs in the area of immediate personal relationships
- A. increasingly mature relationships in home and family life and with adults outside the family
- B. successful and increasingly mature relationships with age-mates of both sexes.

III Needs in the area of social-civic relationships
- A. responsible participation in socially significant activities
- B. social recognition

IV Needs in the area of economic relationships
- A. emotional assurance of progress toward adult status
- B. guidance in choosing an occupation and for vocational preparation
- C. wise selection and use of goods and services
- D. effective action in solving basic economic problems

For each of these needs suggestions were made for science content and teaching methods. For example, meeting student needs in the area of social-civic relationships called for integration of school and community activities and the study of environmental problems. This was a forerunner of our current emphasis on science/technology/society. Factors to be considered in planning an approach to community problems and in judging student growth of sensitivy were:

1. The dependence of the individual's material well-being upon social organizations and relationships

2. The sciences as a part of a growing heritage of knowledge

3. Social conditions as influenced by scientific and technological developments

4. The life of the individual as influenced by scientific and technological developments.

5. The democratic control of social development

Great emphasis was placed on the application of problem-solving and other processes of science, including the use of operational definitions, in life-like situations rather than on study of the separate sciences organized in traditional ways. Individual research projects were suggested that could be inserted into the common science program... young people will be helped to achieve (reflective thinking skills) only by wide successful experiences in attacking and surmounting the problems with which novel situations confront them and in adjusting themselves accordingly, and this adaptability, resourcefulness, and self-criticism will be exhibited mainly in situations similar to those of which they have had previous experience...these must be situations in which young people meet their needs and thus have their interest aroused, ... reflective thinking will be made more effective if this experience is fortified in later adolescence by a conscious awareness of the processes of reflective thinking." (20:307-308)

The issue of how to cover the required material when students are heavily engaged in time-consuming research was discussed. It was acknowledged that students could discover for themselves only a little of what they needed to know but the value of individual research was in the coverage it provided of "attitudes and habits of reflective thinking...and in the understanding it gives of how the knowledge of science gained by the student from description was attained in the first place." (20:317)

The Eight Year Study This major research effort was conceived in the early 1930's to apply the principles of Progressive Education to secondary schools whose traditional curricula were then determined largely by college entrance requirements. This fact stifled innovation just when student populations were changing as more and more non-college bound students were attending. The Commission on the Relation of School to College of the Progressive Education Association was organized in 1930 to investigate this problem (1). They discovered first that only one-sixth of those who entered high school ever entered college. Half dropped out before graduating from high school. In addition they found:

Schools failed to give students a sincere appreciation of their heritage as American citizens.

Students were not adequately prepared for the responsibilities of community life.

Schools neither knew their students well nor guided them wisely.

Schools failed to create conditions necessary for effective learning.

Creative energies of students were seldom released and developed.

The conventional curriculum was far removed from the real concerns of youth.

Most graduates were not competent in the use of the English language.

There was little unity in the work of the high school. Subjects were isolated from each other and there was little continuity from one year to the next.

Very few principals understood their work in terms of democratic leadership of the community, teachers and students.

The relation of school to college was unsatisfactory to both institutions.

To attack these and other deficiencies of secondary schools a national study was innaugurated in which thirty experimental high schools or school districts were identified which were willing to make radical changes in their programs provided their graduates would be accepted by the colleges without having completed the usual preparatory program. By 1932 over 300 colleges and universities had agreed to accept graduates of the experimental schools merely on the basis of the schools' recommendations rather than the usual scores on entrance examinations. The experimental schools were both public and private and located throughout the country.

This was called the eight year study because the innovative curricula that were developed were evaluated by the examination of the achievements of the same students over an eight year period, four in high school and four in college. For this purpose 1475 experimental students were matched with the same number in non-experimental programs.

Planning for curriculum revision was carried on independently in each school by local faculty groups. However, the general life of the school and methods of teaching were to be based on what was then known about ways in which humans learn and know. From this it followed that students were to work together cooperatively at tasks that were clearly related to their purposes. Furthermore, high schools were to rediscover their chief reason for existence which was identified as the promotion of the democratic way of life. Learning of particular subjects was subordinate to this. American education was to be permeated with the spirit of experimentation.

The extent to which school programs were actually modified to take advantage of their new freedom varied greatly. In most cases changes were in the direction of breaking down barriers between subjects, relating school to community life, greater involvement of parents in school affairs, problem solving learning activities, and cooperative teacher-pupil planning as well as group planning by teachers having differing subject backgrounds.

At the conclusion of the study it was found that deviations from the traditional college preparatory programs did not diminish the students' readiness for the responsibilities of college. In fact, students from the schools that made the most fundamental curricular changes achieved distinctly higher standing in college than that of students from control groups with whom they were matched (1:117). Apparently independent study and problem-solving skills acquired by experimental students were more important preparation for advanced learning than the study of prescribed subjects. Hence, it was argued that secondary schools could be trusted with greater freedom in curriculum developemt than the existing college entrance requirements permitted.

Examples of Innovative Programs: The Core curriculum

A common approach to overcoming problems inherent in the separate subject curriculum came to be known as the core curriculum. This was a program intended for the general education of all students which often tended to focus on real-life problems as a means for stimulating the study of a wide range of subjects. Cooperative planning by teams of teachers was required . Frequently students were involved in certain levels of planning as well. Considerable planning was required because the core was not a textbook oriented program. Resource units were often developed which drew upon a wide range of resources from throughout the school and the community. Learning activities frequently involved cooperative group work and individual research projects. Usually two class periods per day were devoted to the core. In addition, students normally took two or three regular school subjects.

In the Altoona Senior High School (21:12) four different levels of core were developed for the tenth grade. These were for college-bound, commercial, average and low groups. The core was known as "everyday problems." The two class periods per day made possible student projects, library work and short trips into the community. The programs were taught by four teachers representing social sciences, natural sciences, home economics and English. They had a common planning period each day. Summer time was also devoted to developing resource units which bore such titles as Orientation to the New School, Family Relationships, Consummer Problems, Communication, and Conservation of Human and Natural Resources.

Similar programs were develped in the Denver and Des Moines schools. At the Radnor High School in Wayne, Pennsylvania a two-year seventh and eighth grade core was developed which focused on home and community living. The science contribution consisted of studies related to weather, climate and other aspects of physical geography while the math contribution included studies of size, distance, map making, data collection and organization, graphing, quantitative problem solving, real estate and taxes.

The senior year probram at Radnor included a "cooperative core" intended mainly for the non-college bound. it was a vocationally oriented work-study program which called for two weeks in school and two weeks on some job for each student. This required extensive cooperative planning by teachers and employers who frequently had to create the part-time jobs. Each of the regular subject areas contribvuted to the program. Included was a math program common to all students which was supplimented by individualized instruction adapted to the unique needs of each student. Science topics in the core included The Automobile, Use of Electricity in the Home, and The Importance of Local Industry.

Fusion of Two or More Subjets was a common practice in schools not going so far as to develope a core program that integrated all or most subjects. At the Baldwin School in Bryn Mawr, Pennsylvania a tenth grade life science program and a two year course in physical science, integrating chemistry and physics in grades eleven and twelve were developed. Teachers at the Bronxville High School in New York developed a three-year broadfield science sequence (21:79). The tenth grade focused on the human body and its evolution while the eleventh grade dealt with the nature of the environment and uses we have made of natural forces. In the twelfth grade students considered the place of humans in the universe with emphasis on constant change and evolution in the areas of earth science and astronomy. Methods of controlled experimentation, problem solving and the social implications of science were stressed. Of particular interest at Bronxville is the fact that the chairpersons of all subject departments held meetings with teachers of all grade levels, K-12, to coordinate and articulate the scope and sequence of the entire curriculum of all grades.

Man's relationship to the environment became tha major integrating theme for the science program at the Cheltenham High School in Elkins Park, Pennsylvania (21:104). The tenth grade focused on the biological environment. In the eleventh year references were made to effects produced by physical forces on the biological environment and in other ways that biology was related to physics. The twelfth year dealt with the composition of the environment and was

intended to show relationships between chemistry, biology and physics. Teacher-developed units replaced textbooks as the chief organizers of the program. Further work in bacteriology and qualitative analysis were available for interested students through clubs.

At the New Trier Township High School in Winnetka, Illinois a unified English-science course met for ten hours per week (21:494). Of these, three were taught by English teachers, four by science teachers and three were devoted to individualized study and community work. There was considerable student-teacher planning with emphasis on the development of democratic values through small group activities. Teachers reported that this method on integrating English with another subject afforded a considerable saving intime and energy because of the use of common subject matter.

A unique feature of the science program at the Tower Hill School in Wilmington, Delaware was the development of a general physical science course for all students in the eleventh grade (21:617). This was followed by twelfth grade electives in chemistry and physics for those wishing a more intensive study of science.

Major Program Changes Probably the most extensive changes in school programs were to be found at the Dalton School in New York and the Lincoln School associated with Teachers College, Columbia University. The K-12 Dalton School for girls emphasized an individualized self-paced approach in which even the high school had no fixed class schedule (21:112). Pupils felt that more than two classes per day left too little time for their work that followed individual study guides developed cooperatively in each class about once a month. This free schedule permitted many trips by individuals, small groups and even classes - some even out of town. The work of each year was organized around a central theme. For example, the theme for grade ten was "The play of science in giving a greater control in shaping the character of society." An interesting feature of the freshman program was the running of a nursery for young babies in connection with the study of child care and human biology. This program was run largely by a pediatrician and nurse.

The experimental Lincoln School broke through the barriers that separated special subjects and built an integrated, functional curriculum which drew on all fields for content (21:460). For example, an eleventh grade course which integrated math and science was developed along with other courses which fused other subjects. This course was team-taught bu a math and a science teacher. In other grades math was linked to other subjects including science, shop, cooking and social studies. Because of the

experimental mission of the school programs tended to change frequently. At one point Euclidian geometry was replaced largely by analytic geometry. At another, a seventh grade course was developed that linked science, math and social studies. Many ideas developed at the Lincoln School were were adapted and employed in other schools throughout the country.

The Eight Year Study, then, was an attempt to break from the traditional subjects found in high schools dominated by a college preparatory goal and develop alternative programs that had relevance for the full range of students in the schools. The major finding of the study was that indeed, the study in high school of subjects patterned after college freshman courses is not the best way to prepare for college or for anything else. Programs that emphasized independed study and problem solving skills, and subject matter that emerged from the study of real-life problems provided superior preparation for higher education and for life itself.

Unfortunately, many of the innovations developed in the thirty schools did not survive for long after the experiment. Lack of understanding of non-traditional programs by the public and many teachers, and the pressures of World War II which began about the time the experiment concluded were undoubtedlyu important forces bringing about a regression in many schools to the more familiar sequence of subjects. Yet, many innovations of the Progressive Education era have survived in many places. Student guidance programs are an example. Through the post WW II years emphasizes have changed. The 1960's and 70's saw a reaction to everything that sputnik represented in terms of the perceived lack of American competetiveness in science and engineering. PSSC, CHEMS, CBA, BSCS, and the "new math" emphasized pure science. The inclusion of applications and technology were rejected by their authors.

The goal of these and other courses developed during these two decades was to have students learn the "structure of the disciplines" becauses it was believed that the possession of knowledge in this form was the best preparation for applying it in real-life situations after graduation. Yet, most students failed to find this relevance in these courses and many of their teachers failed to implement many of the inquiry-oriented activities in these programs that made them scientifically valid. As a result, today the advocacy of such integrative themes as science/technology/ society and environmental education and other concerns over relevance of schooling are strikingly similar to reactions of Progressive educators of the 20's and 30's against the pure subject approaches then in vogue.

How to make the newer curricula emerging in the 90's catch on and last this time? First, we must recognize that reform of science and math education cannot take place apart from reform of all aspects of the K-12 program. Our professional organizations will have to work more closely with those representing other subject areas. In addition, the public has to be given a rational and justification for innovations that have proven to be successful. School programs are affected as much by newspaper editors and politicians as by teachers and curriculum specialists. Everybody has been to school at one time or other and many laypersons are uncomfortable with school programs and practices that are different from what these were like when they were in school. In other words, the public has to be sold on the desired changes or they won't take place because they won't be supported emotionally or financially.

Much of the cost of the reforms that are now unfolding will be for the time needed for teacher planning. We have seen how much time and effort and leadership are required to foster collaboration between teachers of different subjects, and these cost money. On the other hand, not all planning needs to be conducted in the schools. One reason that innovations from the Progressive era failed to last may very well be that too much creativity was demanded of every teacher. We should take advantage of the format of the developmental curriculum projects of the 1960's in which materials were written in summer writing conferences and went through a series of trials in the schools followed by revisions before they were published and distributed. Integrative resource units dealing with such core topics as S/T/S and environmental issues can be developed on a national basis by summer writing teams and these could be adapted for local use by teacher-pupil planning groups. Pupil involvement in planning is essential if pupils are to have a sense of ownership of their programs. It is difficult for teachers by themselves to anticipate specific student needs.

At this point it should be apparent that many of the suggestions for reform of science and math education have their roots in practices which emerged during the Progressive era a half-century or more ago. Both movements have been concerned with the relevance of the curriculum to contemporary and future needs of students. Both have stressed integration of subject matter, horizontally so that relationships between subjects and between school and life are apparent, and vertically so that each year's work bears a relationship to the next. There are lessons to be learned from past curricular experimentation and we should not fail to take advantage of them.

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